

# Highly Reusable Space Transportation Study

## Preliminary Modeling Definition Document

### A Catalog of Spaceport Architectural Elements with Functional Definition

October 1997

A Tool for Assisting Developers  
of Future Space Transportation Systems

Prepared for the

Highly Reusable Space Transportation  
(HRST) Synergy Team

- Government, Industry, Academia -

## ABSTRACT

This document is provided as an aid or tool for developing architectural concepts leading to commercially viable space transportation in the 21<sup>st</sup> century. To provide the required visibility of the overall system architectural relationships, a *catalog* of generic spaceport facilities and their vehicle support functions are presented in modules. These modules provide the system architectural developer an understanding of the ground infrastructure dependence and why this dependence drives/constrains the total system flight rate capability, labor, logistics support, as well as the initial investment. This understanding will allow the developer to iterate and optimize concepts to attain commercial viability. The spaceport modules have been formulated to be responsive to the developer by allowing selection of only those modules and functions required by the concept. The tool is to be very broad to allow accommodation of most any space launch & landing approach.

*The document is in a preliminary state and requires further development, such as adding quantitative data. The document is provided, however, to provide architectural visibility during early concept development.*

## ACKNOWLEDGEMENTS

The J. F. Kennedy Space Center members of the Spaceport Synergy Team that prepared this document pulled together the experience of both government, prime contractor industry, and small business members, and are here acknowledged:

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## INTRODUCTION

The object of this document is to provide an aid or tool for developing Space Transportation System architectural concepts leading to commercially viable space transportation in the 21st century. The catalog will provide a modular overview of major spaceport elements, and their top functions, down to the measurable level to provide visibility and understanding of the ground side of Space Transportation Systems.

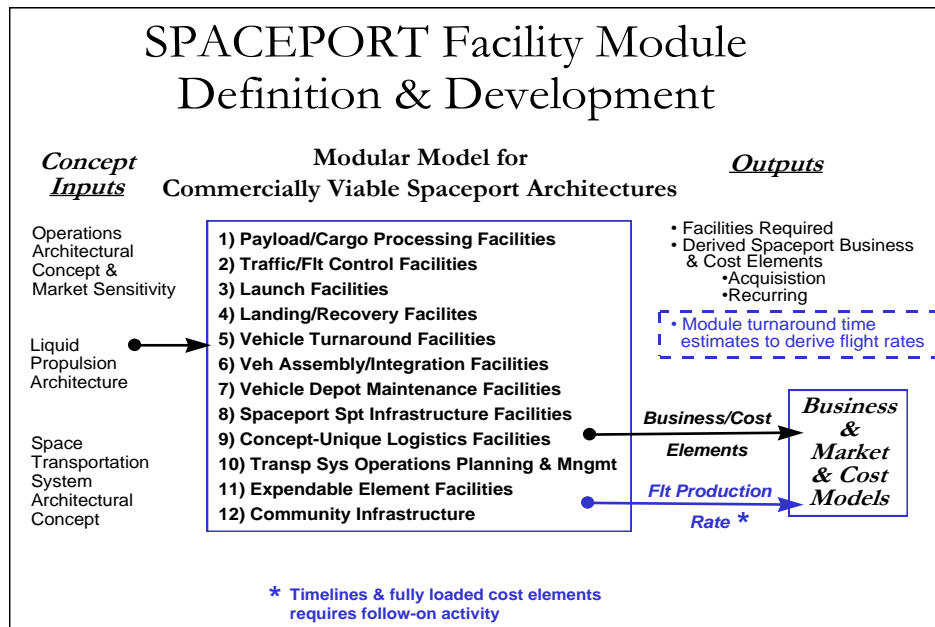
This catalog of selectable spaceport architectural elements, with selectable required functions, can support transportation concepts for present and foreseen varieties of future vehicle systems, and their possible operational modes. These transportation concepts include single and multi-stage, vertical or horizontal launch and landing modes, as well as ground launch-assist approaches.

The application of this document is presently limited to providing identification and visibility of vehicle ground-support major elements, and those top-level functions required within these elements. The functions are presented in modular format.

***Concept developers can select only those elements required by their concept.***

The result will provide definition of the spaceport required of that specific concept. A future, more mature, version of this catalog could have data on cost, process flow time, and headcount, to support a life cycle cost or commercial business models.

Additionally, a future version of the model could contain information on the investments required to establish the spaceport facilities and infrastructure. It is intended this catalog be used as an interactive tool to allow an iterative design process to occur and, ultimately, arrive at a truly affordable or commercially viable space transportation system.



## HOW TO USE AND INTERPRET THIS CATALOG

### ***Spaceport Modules***

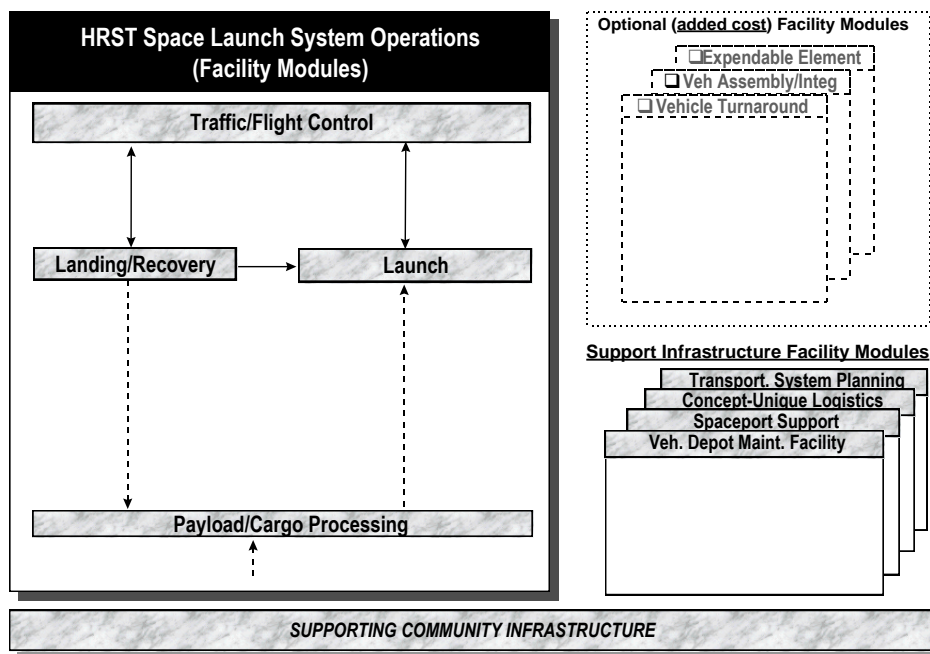
The HRST Spaceport Model Example chart presented below characterizes the principal functions expected of any HRST Space Launch System Operations concept. Each functional block in the diagram is represented in this document by a 'module' title. This catalog describes each of these modules in functional detail, in many cases with varying options for the architect to select. Also, in many cases the functional outline goes down to a level that is measurable.

### ***Generic Spaceport Functional Interdependence***

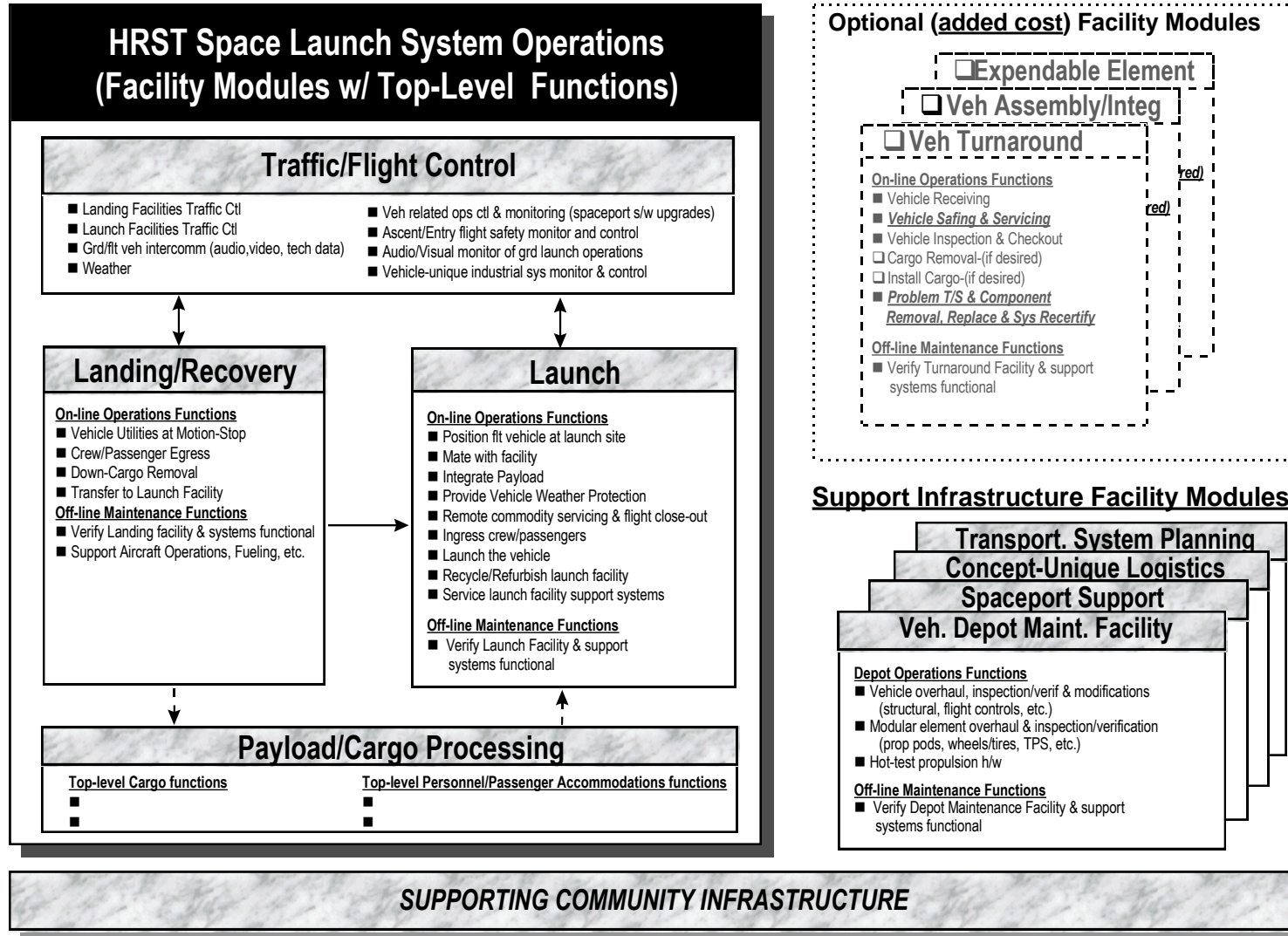
This catalog allows vehicle architects to examine their design in the context of each spaceport module to determine if the design requires the functions listed (or even the facilities listed if no functions within the module are required). If the vehicle design requires any of the functions, then the facility function cannot be eliminated. The result is that the spaceport infrastructure will carry the cost and cycle times associated with the dependence on the function and the facility.

### ***Deriving Highly Reusable & Affordable Space Transportation Architectures***

The next page shows the example model (the one shown below) with some top-level functions defined, based on some given vehicle concept. The challenge for the HRST architect is to come up with a vehicle design that needs only those top-level spaceport facilities and functions shown in the figure. In other words the object is to understand vehicle system functions in the context of their ground interaction so as to select as few functions and modules as possible. In this sense this catalog can be used for vehicle design, as well as well as spaceport development—and is its primary purpose.



# HRST Spaceport Model Example



### ***“Walk-through” of the HRST Spaceport Model Example Chart***

*Launch* and *landing/recovery* of the flight vehicle are cardinal points of the space transportation system. A wide variety of flight vehicle-concept options are accommodated in the modules.

*Payload/cargo processing* is Module 1, in accord with importance of the 'customer'. Payload-up (and down) are shown to have two basic operational options: Payloads can be loaded in or on the vehicle either during a *vehicle assembly/integration* activity, or at the *launch* site. Downloads can exit the vehicle either at the *landing/recovery* or later, during *vehicle turnaround*. Four payload options are envisioned and each fit the module architecture:

- 0- attached externally to the vehicle
- 1- containerized and loaded internally
- 2- standard payload carrier
- 3- custom built-in to the vehicle.

The foregoing 'big picture' chart includes options for *vehicle depot maintenance*, to be periodically expected of all concepts. It also shows the *system operations planning & management*; *traffic/flight control*; *spaceport support infrastructure*; and *concept-unique logistics* essential to any concept.

A *community infrastructure* module also outlines the considerations for launch site development in totally new or isolated locales.

### ***Final Word About the Catalog of Spaceport Architectural Elements***

The spaceport modules presented herein are a catalog of options responding to the wide range of anticipated vehicle concepts. The concept-specific architecture of each module, as it is developed, will be driven in scope and content by flight vehicle architecture. Ground facilities, equipment, manpower, and operations (and resultant cost) are directly proportional to complexity of vehicle architecture and systems design. Increased quantities of different-type systems, their degree of complexity and associated hazards, will all mandate appropriate accommodation as outlined in these functional spaceport modules.

### ***The “Input Modules”***

In constructing this catalog of spaceport architectural elements, the Synergy Team decided that “input modules” would be required for translating a vehicle design into spaceport functional interactions (i.e., the functions seen in the modules). In the future, these “input modules” can be used for defining a software model version of this catalog. For now it serves provides visibility to the architect of those vehicle functions that will drive the affordability, reusability and responsiveness of the overall architecture.

- **OPERATIONS ARCHITECTURAL CONCEPT & MARKET SENSITIVITY INPUT MODULE**  
This module is an introduction to the spectrum of prime vehicle concept/system characteristics accommodated and addressed in the modules.
- **LIQUID PROPULSION ARCHITECTURAL CONCEPT INPUT MODULE**  
This module is an introduction to the spectrum of second-level structural, *propulsion*, and fluids characteristics addressed in the modules. The first focus on **internal vehicle interfaces**, structural and propulsive, is noted.
- **SPACE TRANSPORTATION SYSTEM ARCHITECTURAL CONCEPT INPUT MODULE (Exclusive of Propulsion)**  
This module is an introduction to the spectrum of non-propulsive second-level systems characteristics 'interfaces', ground-to-vehicle; and areas of focus such as fluids, payload accommodations, maintainability, GN&C, environmental control, and life support.

The above modules are basically a concept designers 'shopping list' of basic vehicle characteristics with additional focus on those elements that drive ground infrastructure. They represent the topics presented in the facilities functional Modules 1 through 12 presented in the body of this document.

The twelve subsequent modules are 'facilities-oriented' and form an outline or breakdown of functions describing the wide variety of ground processing scenarios to be expected in a variety of possible future vehicle concepts. Several of the modules are annotated with tables suitable for identifying quantified data on GSE and commodities.

# **Catalog of Spaceport Architectural Elements**

## **(Generic Modules)**

## OPERATIONS ARCHITECTURAL CONCEPT & MARKET SENSITIVITY INPUT MODULE

*The integrated operations concept of the vehicle and spaceport infrastructure will determine the quantity of these modules required to support the concept. The simplest overall concept can be expected to require the least quantity of modules and, therefore, the highest flight rate at the lowest recurring cost*

The following represents the spectrum of concept architectures applicable to this HRST functional module exercise:

- Vertical launch - horizontal landing
- Vertical launch - vertical landing
- Launch assist - (non-vertical); horizontal landing (mag-lev et al)
- Micro-wave beaming/ vertical launch - horizontal landing
- Multi-stage vehicle
- Airborne launch - horizontal landing
- Inflight oxidizer-fill option
- Fleet size - quantity of spaceport modules
- Flight control mode
- Unmanned
  - = Autonomous control
  - = Remote-control from ground
- Crew-operated vehicle
- Fleet size
  - Quantity of modules
  - Quantity of vehicles
- Passenger and/or cargo accommodations

## LIQUID PROPULSION ARCHITECTURAL CONCEPT INPUT MODULE

*Drives total system infrastructure as passed-on through vehicle systems for spaceport infrastructure accommodations which must ultimately support the vehicle design*

AFFORDABILITY of the overall transportation system architectural concept starts with propulsion

Traditional vehicle structural architecture (tankage, and the multitude of *propulsion* support systems) are always tailored to engine propulsion system architecture and the interfaces:

- Structural interfaces (quantity)
  - Quantity of stages or flight elements (propulsion modules, etc) that must be assembled/ integrated and verified
  - Ordnance separation systems and range safety
- Propulsion packaging architecture
  - Totally integrated with only one set of tanks
  - Separate systems:
    - = Main propulsion system (MPS)
    - = Orbital maneuvering system (OMS)
    - = Reaction control system (RCS)
    - = Power drivers
- Liquids interfaces, flight vehicle and ground (quantity)
  - Type of liquid (hazardous/ non-hazardous; long or short term storability) and quantity of interfaces supporting propulsion functions
  - = Propellants for ascent propulsion
    - = Propellants for vehicle steering & control in space (reaction control systems)
  - = Propellants for de-orbit propulsion
  - = Auxiliary power propellants
  - = Hydraulic power control fluids
  - = Thermal control fluid

- Gaseous interfaces, flight vehicle and ground (quantity) that support the propulsion function
  - Type of gas (hazardous/ non-hazardous; high or low pressure) and quantity of interfaces
  - = Inerting purges
  - = Pressurants
  - = Valve Actuation/Control
- Power (electrical) supporting the propulsion function
  - Type and quantity of interfaces
  - = DC/ AC and frequency; high/ low voltage; single-phase/multi-phase
- Environmental controls and their interfaces that support the propulsion function
  - Processing facility(s)
  - Launch site environmental elements (weather, lightning)
  - Purged compartments
  - Heat shields/ TPS
  - Heating/ refrigeration
- Communications (voice, command & control) supporting propulsion functions
  - Type and quantity of interfaces
  - Control software architecture
  - Flight control (ground/ range or autonomous: ground tracking or space-based assets)

# SPACE TRANSPORTATION SYSTEM ARCHITECTURAL CONCEPT (Exclusive of Propulsion)

## INPUT MODULE

Remainder of the space transportation vehicle system (i.e., those systems excluding propulsion) drive the remainder of the Spaceport infrastructure accommodation—i.e., spaceport facilities, equipment, and resources which must “support the design”

AFFORDABILITY of the overall transportation system architectural concept  
- including the spaceport infrastructure - starts with propulsion  
and is adequately assessed only when all vehicle systems,  
and their operability and maintainability factors, are thoroughly examined.

Traditional vehicle structural architecture (tankage, and the multitude of *propulsion* support systems) are always tailored to engine propulsion system architecture and the interfaces:

- Liquid Interfaces, Flight Vehicle & Ground (quantity)
  - Type of liquid (hazardous/non-hazardous; long for short-term storability) and quantity of interfaces
    - = Power reactants
      - = Hydraulics for vehicle control & other functions (e.g., retracting stage umbilicals separation devices, landing gear retract/extend, ground steering & braking, etc.)
      - = Thermal control of avionics, fuel cell power system, hydraulic system, and environmental control & life support systems (ECLSS)
    - = Lube oil
    - = Water systems (NASA specifications)
    - = etc.
- Payload Accommodation Architectural Concept
  - OPTION 0: Payload attached externally to the launch vehicle
    - = Transparent to launch vehicle and remotely operated
    - = Avoids payload structural/ mechanical accommodations intrusive to vehicle mold-line (no payload bay)
    - = Payload service accommodations (power, thermal/ environmental management, ducting, purging, etc.) self-contained and transparent to
  - = No contamination control required by launch vehicle

- = Flight vehicle provides auto alignment and attachment features for remotely operated attachment during launch preparations
- = Payload carrier truly self-sufficient
  - o May be designed for re-entry from space if required
  - o "Module" may serve as upper stage
- OPTION 1: Containerized payload
  - = Transparent to launch vehicle
  - = Requires payload structural/ mechanical accommodations intrusive to vehicle mold-line (payload bay)\_
  - = Payload service accommodations (power, thermal/ environmental management, ducting, purging, etc.) self-contained and transparent to launch vehicle
- = No contamination control required by launch vehicle
- OPTION 2: Standard payload carrier
- = Launch vehicle provides all required payload support services through standardized launch vehicle common interfaces
  - = Requires vehicle-to-payload interface test and verification
  - = Requires launch vehicle contamination control
- OPTION 3: Payload "custom-built" into launch vehicle bay - "Shuttle-like"
- = Each flight built-up from custom design and fabrication/ installation
  - o Payload bay reconfigured for each flight - e.g., structural service kits
  - o Launch vehicle contamination control to all levels of cleanliness
  - o Payload-unique accommodations removed from launch vehicle after each flight
- Maintenance Accessibility
  - Towers, platforms, access kits (type and quantity)
- Mechanical Systems Approach
  - Doors/hatches
  - Aero surface hinge-line sealing mechanisms
  - Landing gear/tires
- Guidance, Navigation & Control Systems
  - Autopilot guidance algorithm development/verification (ascent, orbital, entry/landing guidance modes)
  - Navigation systems (ascent/descent & orbital)
  - Flight control systems (actuation control, any special dedicated hardware requirements such as body-mounted accelerometers, rate gyros, etc. due to

- complex vehicle structural dynamics)
  - Avionics & power interfaces
  - Hardware/systems functional management (e.g., fault management, health verification, gimbaled engine collision avoidance routines)
- Vehicle Environmental Control Architectural Concept
  - Approach to control delta pressure, rain/water intrusion, hazardous gas accumulation, structural thermal management
- Communications (voice, command & control) supporting all functions required of vehicle in addition to propulsion
  - Type and quantity of interfaces or RF support
  - Control software architecture
  - Vehicle GN&C communications (communicating tracking, ranging and orbital traffic from space and ground)
- Life Support functions
  - fluids
  - gases
  - food
  - waste

# ***Generic Operational Spaceport Modules***

1. Payload / Cargo Processing Facilities
2. Traffic / Flight Control Facilities
3. Launch Facilities
4. Landing / Recovery Facilities
5. Vehicle Turnaround Facilities
6. Vehicle Assembly / Integration Facilities
7. Vehicle Depot Maintenance Facilities
8. Spaceport Support Infrastructure Facilities
9. Concept Unique Logistics Facilities
10. Transportation System Operations Planning and Management
11. Expendable Element Facilities
12. Community Infrastructure

# 1. PAYLOAD/CARGO PROCESSING FACILITIES MODULE

TOP-LEVEL FUNCTIONS LIST: (select one)

Top-Level Cargo Functions

Top-Level Personnel/Passenger Accommodations Functions

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## **Top-Level Cargo Functions**

- Prepare facility for payload arrival
- Receiving/inspection
- Integrate the elements
- Verify P/L functional
- Prepare P/L canister
- Integrate P/L with canister; verify cleanliness
- Perform fluids servicing
- Perform weight, CG & balance
- Load P/L on transporter
- Remove down load from canister
- Remove P/L from canister; deservice
- Package P/L in shipping container; ship

## **Top-Level Personnel/Passenger Accommodations Functions**

- Receive/inspect passenger module
  - Off-load expended commodities and waste
- Prepare and load life support commodities
  - Breathing air, food and beverages, waste treatment
- Verify module functional
- Load personnel tools/equipment/luggage
- Transfer/integrate module to/with vehicle
- Provide mission briefing for crew/passengers
- Transport personnel to-from vehicle

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- Prepare facility for payload arrival
  - Work control system on-line and functional
  - Information and management systems functional

<b>Systems</b>	<b>Quantity</b>
Command/ control terminals	
LAN (personal computers)	
Printers	
Readers	

- Logistics staging area/ tool crib(s) sited and operational
- Verify hazardous warning systems functional:

<b>Systems</b>	<b>Quantity</b>
Paging system	
Toxic vapor detectors	
Smoke/ fire detectors	
Oxygen depletion detectors	
Hydrogen vapor/ fire detectors	

- Verify firex system functional

<b>Systems</b>	<b>Quantity</b>
Pumps, tanks, and controls	
Hose Reels	
Sprinklers	
Fire extinguishers	

- Environmental contamination control

<b>Systems</b>	<b>Quantity</b>
Toxic liquid spill handling/ control	_____
- Water flush and drain . . . . .	_____
- Catch basin(s) . . . . .	_____
- Ventilation and air scrubber(s)	

- Verify lifting devices/ cranes functional

<b>Systems</b>	<b>Quantity</b>
Bridge cranes	
Derricks/ hoists	
Mobile cranes	
Jacks (facility/portable hydrasets etc.))	

Manlifts	
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- Clean/ verify facility cleanroom
- = Filters serviced, sampling systems and HVAC functional

<b>Clean Rooms</b>	<b>Quantity</b>	<b>Class</b>
Payload-specific area		
Sampling system(s)		
Filter system(s)		
Air handlers		
Major doors and seals		
Shoe cleaners		
Personnel attire (bunny suits)		

- Verify facility, and GSE power support systems functional:

<b>Interfaces</b>	<b>Quantity</b>
Alternating current	
Direct current - 28Volt	
Direct current - 270V	
Power conditioning/ filtering (Spike/ surge protection)	
Uninterruptible supplies (UPS)	
Back-up generators	
Grounding systems	
High voltage GSE (13KVA, etc)	
Lightning protection	
Others (specify)	

- Verify command and control systems functional and software ready and verified:

<b>Systems</b>	<b>Quantity</b>
Auxiliary propulsion functions	
Fuel-cell power functions	
Guidance-nav-control functions	
Purge, vent, drain functions	
Hydraulic power functions	
Electrical power functions	
Cooling systems (thermal mgmt.)	

Communication & tracking systems	
Life support system functions	
Utilities feed systems for module;	
- Power . . . . .	_____
- Water . . . . .	_____
- High pressure gases . . . . .	_____
- Firex (Halon, etc.) . . . . .	_____
- HVAC . . . . .	_____
- OTV . . . . .	_____
- OIS . . . . .	_____
- Mechanical subsystems . . . . .	_____
- Data processing subsystems . . . . .	_____
- Others (specify) . . . . .	_____

- Lighting/ illumination functional and ready

<b>Systems</b>	<b>Quantity</b>
General area lighting	
Special lighting/ cleanroom functions	
Portable lights	
Emergency lighting	

- Verify GSE and facility systems functional and ready to support:

<b>Systems (mechanical hardware; hoses, control panels, etc.)</b>	<b>Quantity</b>
Payload propulsion	
Fuel-cell power	
Guidance-nav-control	
Purge, vent, drain	
Hydraulic power	
Electrical power	
Cooling systems (thermal mgmt.)	
Communication & tracking systems	
Utilities feed systems for module;	
- Power . . . . .	_____
- Water . . . . .	_____
- High pressure gases . . . . .	_____
- Firex (Halon, etc) . . . . .	_____

- HVAC . . . . .	_____
- OTV . . . . .	_____
- OIS . . . . .	_____
- Mechanical subsystems . . . . .	_____
- Data processing subsystems . . . . .	_____
- Others (specify) . . . . .	_____

- Roll-up style payload ground processing/ access structure positioned for payload arrival
  - Facilitized payload access platforms configured and ready to support
  - Upon arrival of payload transport vehicle, open facility access doors, verify transfer path clear
- Receiving/ inspection, et al to be completed at later date

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## 2. TRAFFIC/FLIGHT CONTROL FACILITIES MODULE

### Spaceport Module Coordination

#### TOP-LEVEL FUNCTIONS LIST

- Landing facilities traffic control
  - Launch facilities traffic control
  - Ground/flight vehicle inter-communications systems management and control
    - Audio/video/tech data; flight vehicle-to/from-ground
  - Weather advisory for launch, landing, and ground operations
  - Vehicle-related launch/flight/landing/ground operations control and monitoring
    - Spaceport software upgrades (non-flight)
  - Ascent flight safety monitor and control
    - Provide public safety planning and implementation for launch and landing operations
  - Audio/visual monitor of ground launch operations
  - Vehicle-unique industrial systems monitor and control
- 

- Landing facilities traffic control
  - Coordinate operations of multiple flight crews/controllers/ground operations
    - = Schedule landing facilities and distribute plans
      - o Landing Area
        - + Landing pad
        - + Runway
        - + Marine
      - o Traffic control center
      - o Abort site facilities and GSE
      - o GSE
        - + Fixed
        - + Portable
      - o Conventional aircraft (spaceport-owned)
      - o Communication facilities
    - = Schedule landing windows
      - o Primary/backup

- o Scrub contingency
  - o Abort sites
- = Coordinate flight operations of conventional air transports
  - o Landing
  - o Takeoff support
- = Schedule hazardous operations
- Alert, mobilize, and coordinate emergency systems (fire/rescue/medical)
- Coordinate operations with external (non-spaceport) transportation system functions
  - = Air space coordination
  - = Proximity space launch coordination
  - = Nearby military operations
  - = Ground and marine transportation
- Verify landing facility ready to support landing
- Provide clearance to flight crews/controllers
- Launch facilities traffic control
  - Coordinate operations of multiple flight crews/controllers/ground operations
    - = Schedule launch facilities and distribute plans
      - o Launcher movement (taxi)
      - o Launch pads/runways
      - o Traffic control center
      - o GSE
      - o Abort site facilities and GSE
      - o Communication facilities
      - o Simulation/test/verification facilities
    - = Schedule launch windows
      - o Primary/backup
      - o Scrub contingency
      - o Abort sites
    - = Schedule hazardous operations
  - Alert, mobilize, and coordinate emergency systems (fire/rescue/medical)
  - Calculate and monitor trajectory/impact footprint
  - Verify launch facilities ready to support launch
  - Provide clearance to flight crews/controllers
  - Monitor auto-abort/flight termination systems
  - Initiate abort/flight termination sequences

- Coordinate operations with other transportation system functions
  - = Air space coordination
  - = Abort sites
  - = Proximity space launch coordination
  - = Nearby military operations
  - = Ground and marine transportation
- Space traffic control
  - = Monitor and avoid orbital debris
  - = Monitor and avoid orbiting spacecraft
  - = Rendezvous planning
- Ground/flight vehicle inter-communications systems management and control
  - Verify audio/visual signal reception
  - Verify umbilical connections
  - Operate tracking equipment
    - = Antennae tracking stations
    - = Receivers
    - = Monitor signal acquisition
    - = Maintain tracking equipment (light maintenance)
  - Audio
    - = Acquire and distribute audio signals from onboard microphones
    - = Plan and allocate audio channels
      - o Intercom/OIS networks
    - = Maintain audio equipment (light maintenance)
    - = Operate recorders
    - = Provide playback
  - Video
    - = Plan and allocate video channels
      - o Video switch/distribution panels
    - = Acquire and distribute video signals from onboard cameras
    - = Remotely operate video cameras
    - = Operate recorders
    - = Provide playback as required
    - = Maintain video equipment (light maintenance)
  - Data
    - = Manage land line data links
      - o Launch facility data links including GSE control/data lines
      - o WAN (Internet) links

- o Security
- = Manage and operate RF/telemetry data links
  - o Antennae/Receivers/Mod/Demod
  - o Frequency/protocol configuration
  - o Uplink/Downlink
  - o GPS/IRIG/SatComm
- = Record/archive real-time data
  - o Data retrieval/analysis
  - o Data playback (training, simulation, analysis)
- Weather advisory for launch, landing, and ground operations
  - Operate and maintain field equipment
  - Monitor and distribute weather data
    - = Ground operations
    - = Launch operations
    - = Landing Operations
    - = Abort sites
  - Exchange information with other weather agencies
    - = Hurricane center
    - = National Weather Service
    - = Local television and radio stations
  - Analyze and forecast weather conditions
    - = Wind speed and direction
      - o Winds aloft
      - o Windshear
    - = Temperature
    - = Precipitation
    - = Lightning
    - = Cloud cover
    - = Dew point
    - = Barometric pressure
    - = Meteor showers
    - = Solar radiation/flares
    - = Compose and issue advisories
      - o Lightning
      - o Wind

- o Hail
- o Sandstorm
- o Heavy rain
- o Tornado
- o Hurricane

<b>Weather Related Support</b>	<b>Quantity</b>
Instruments	
Weather data points	
Types of data	
Altitude points	

- Vehicle-related launch/flight/landing/ground operations control and monitoring
  - Launch Operations
    - = Validate GSE and facility operation
    - = Power up vehicle
    - = Load and maintain propellants
    - = Validate flight software
    - = Validate GN&C/GPS
    - = Perform vehicle tests
    - = Acquire launch clearance
      - o Space traffic clearance
      - o Ascent flight safety (range) clearance
    - = Engage countdown sequencer
  - Flight Operations
    - = Monitor auto-abort/flight termination systems
    - = Initiate abort/flight termination sequences
    - = Monitor staging
    - = Calculate and monitor trajectory/impact footprint
    - = Monitor and control vehicle subsystems
    - = Monitor and control payload operations
    - = Communicate with flight crew and on-board systems
    - = Provide customer interfaces to payload and mission operations
      - o Remote payload operation
      - o Experiment data distribution
      - o Flight crew communication
    - = Process subsystem performance and failure data
  - Landing Operations
    - = Verify landing facility readiness

- = Verify unique GSE functional and staged for operation
  - = Acquire range clearance
  - = Monitor/initiate abort modes
  - = Monitor and control vehicle subsystems
  - = Safe vehicle subsystems
- Ground and turnaround integration operations
  - = Flight element ground transport
  - = Payload ground transport
  - = Spaceport facility coordination and scheduling
    - o Vehicles
    - o Launchers
    - o Turnaround facility
    - o Launch and landing facilities
    - o Vehicle assembly facility
    - o Maintenance facility
  - = Payload integration support
  - = Vehicle integration support
  - = Payload/vehicle integration support
  - = Final preflight closeout test and verification
- Spaceport software maintenance [information system concept to be developed  
[See module 10]
- Ascent flight safety monitor and control
  - Monitor and control launch range
    - = Provide range safety
      - o Respond to auto-abort/flight termination scenarios
      - o Monitor debris impact footprint
    - = Provide downrange clearance
      - o Air
      - o Marine
      - o Surface
      - o Military
  - Launch operations public safety
    - = Calculate drift patterns
      - o Vehicle debris impact footprint
      - o Vehicle staging impact footprint
      - o Toxic vapor/radiation cloud drift (both vehicle and payload sources)
    - = Notify FAA and local authorities
  - Landing operations public safety

- = Calculate drift patterns
    - o Vehicle debris impact footprint
    - o Toxic vapor cloud drift
    - o Sonic boom
  - = Notify FAA and local authorities
- Ensure environmental law and regulations compliance
- Audio/visual monitor of ground launch operations
  - Plan and operate monitoring equipment
    - = Cameras
    - = Intercomm systems
    - = Fire monitors
    - = Water monitors
    - = Toxic material monitors
  - Record and retrieve
  - Maintain equipment (light maintenance)
- Vehicle-unique industrial systems monitor and control
  - Provide HVAC services at launch vehicle facilities
    - = Toxic vapor emergency purge
    - = Air handlers
    - = Cooling towers
    - = Hydrocarbon monitoring
    - = Energy conservation
    - = Clean room monitors
  - Provide industrial water
    - = Launch facility washdown
      - o Remove hazardous residue
      - o Remove corrosive residue
    - = Fire extinguishing
    - = Fill, monitor, and control reservoirs
    - = Ignition over-pressure suppression [vehicle unique]
    - = Sound suppression [vehicle unique]
  - Provide high voltage electrical power to launch vehicle facilities
    - = Coordinate with electric providers
    - = Provide primary power to major facilities
      - o Monitor transformers
      - o Operate switching network
    - = Provide backup power

- o Auxiliary/emergency generators
    - o Manage isolation and recovery operations
    - o Monitor universal power supply
  - = Ensure load balancing
    - o Plan and control equipment power up
  - Pneumatics control
    - = Inert enclosed critical spaces
    - = Monitor and control air sources
      - o Compressor control
      - o Actuator control
  - Fire detection and extinguishing
    - = Monitor and control halon equipment
    - = Vehicle protection
    - = Launch facility protection
  - Monitor and control lightning protection system
-

### 3. LAUNCH FACILITIES MODULE

TOP-LEVEL FUNCTIONS LIST: (select one)

3.1 Top-Level **Vertical** Launch Functions

3.2 Top-Level **Horizontal** Launch Functions

3.3 Top-Level **Launch Assist** Functions - (mag-lev et al)

3.4 Top-Level **Micro-Wave** Beaming Functions: See Vertical Launch

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#### 3.1 Top-Level **Vertical** Launch Functions Sub-List

(each item expanded below):

- Verify launch facility on-line and functional
  - Position flight vehicle for/at launch site
  - Mate with facility and verify functional interfaces (if any)
  - Integrate payload and/or personnel module with vehicle and verify functional interfaces (if any)
  - Provide vehicle weather protection (if required)
    - Wind, rain, ice, lightning, etc.
  - Perform local servicing of commodities and close-out for flight if required at this module
  - Perform remote servicing of commodities and close-out for flight if required at this module
  - Ingress crew/passengers
  - Launch the vehicle
  - Recycle/ refurbish launch facility
  - Service launch facility support systems
- 

#### 3.1 Top-Level **Vertical** Launch Functions

- Verify launch facility on-line and functional
  - Verify electrical power systems functional
  - Verify pad communications systems functional (OIS, OTV, paging/ warning,

- hazardous gas detection/ alarm systems)
- Verify command and control systems functional
- Verify propellants and gasses storage and transfer systems functional
- Verify access and handling systems functional (elevators, cranes, safety doors, payload-unique handling equipment, weather protection, etc)
- Verify industrial water systems functional (tower/ pad deluge, flame deflector deluge, sound suppression, ignition overpressure, etc)
- Verify fire-ex emergency water systems functional
- Position flight vehicle for/at launch site
  - Transport vehicle to launch pad
  - Position and align for erection (if required)
  - Erect to vertical (if required)
  - Verify position and alignment
  - Remove transportation/ erection hardware (if required)
- Mate with facility and verify functional interfaces (if any)
  - Install/ mate electrical power umbilicals to vehicle and verify all conductor continuity and free of short circuits (if required)
  - Install/ mate communications/ data umbilicals to vehicle and verify functional signal strength and noise levels if required (fiber optics, copper path, etc)
  - Verify RF/ IR communication paths functional between vehicle and facility
  - Position access systems/ equipment required (swing arms, access platforms and hardware protective kits, etc)
  - Structurally mate vehicle to facility and torque fasteners (explosive bolts) for holddown, umbilical carrier plates, and stabilizers, if required
  - Remove any temporary structural supports if required
  - If vehicle was mated to launcher (mobile platform) at prior module, mate/ install launcher to facility and structurally attach to supports
  - Install/ mate cryogenic fluid umbilicals and leak check (if required)
  - Install/ mate toxic fluid umbilicals and leak check (NH<sub>3</sub>, MMH, N<sub>2</sub>O<sub>4</sub>, etc)
  - Install/ mate non-toxic storable liquids umbilicals and leak check (RP-1, alcohol, hydraulic fluid, coolants, H<sub>2</sub>O<sub>2</sub>, water, etc, if required)
  - Install/ mate gaseous umbilicals and leak check ( GN<sub>2</sub>, GHe, GH<sub>2</sub>, GO<sub>2</sub>, air, etc)
- Integrate payload and/or personnel module with vehicle and verify functional interfaces (if any)
  - Perform cargo removal if desired

- = Provide access to payload
- = Position and connect handling equipment
- = Demate payload from vehicle
- = Remove payload, place on transporter and establish required services
- = Remove payload-unique accommodations from vehicle
  
- Install cargo if desired
- = Configure vehicle and install payload-unique accommodations
- = Clean/ verify vehicle cleanliness if required
- = Receive, position, and install handling equipment on payload
- = Install payload
- = Mate payload-to-vehicle interfaces and verify functional
  
- Provide vehicle environmental protection (if required)
  - Position wind/ rain/ hail/ snow protection systems
  - Position/ check electrical continuity of lightning-sensing and protection system
  - Provide/ position vehicle thermal management and control system if used
  
- Perform local servicing of commodities and close-out for flight if required at this module
  - Drain and flush fluid systems as required
  - Replenish, fill or verify fluids and gasses commodities, and verify chemical purity at desired level (if appropriate at this module)
  - Recharge batteries or replace if needed
  - Lubricate and adjust subsystems as required
  - Install ordnance if desired
  - Perform flight and ground systems ordnance installation operations (if required in this module)
- = Establish RF silence (includes no-switching)
- = Remove spent ordnance and install and install new end items
- = Verify stray voltage control
- = Perform electrical mate and configure safe & arm devices
- = Perform range safety interface command checks
- = Verify functional links with space-based assets (if incorporated)
  - Perform any needed cleaning before close-out
  - Remove any access hardware or other non-flight hardware

- Perform close-out photography if desires
- Install close-out covers and access doors and leak check as required
- Perform remote servicing of commodities and close-out for flight if required at this module
  - Clear personnel from pad-blast danger area
  - Load main propellants for flight (cryogenic and high-pressure gasses to flight pressure)
  - Establish steady-state replenish of cryos
- Ingress crew/passengers
  - Prepare crew/ passenger module for ingress
  - Transport personnel to pad for ingress (boarding)
  - Prepare and board flight personnel (flight suits, security/ badge/ identification checks, etc)
  - Stow carry-on items
  - Seat/ secure personnel for launch/ flight environment
  - Close access hatch/ door and remove/ stow access equipment
  - Transport ground service crew to fall-back area
- Launch the vehicle
  - Verify vehicle and environment ready for launch

= Ground support personnel fall-back complete

= Emergency fire and medical equipment and personnel on station

  - Obtain clearances to launch/ fly (if appropriate)
  - Execute auto launch sequence
  - Provide emergency abort flight personnel egress capability
- Recycle/ refurbish launch facility
  - Secure/ safe ground systems (reactivate pre-launch-secured utilities [electrical power, lighting, fire alarms, HVAC, potable water, communications, etc], drain and purge propellant transfer systems, vent and purge high-pressure pneumatics systems, safe high-volume low-pressure facility purge systems, safe ordnance systems, replace personnel restraint systems [safety railing etc])
  - Perform facilities and systems walk-down inspections and document anomalies for repair/ refurb cycle
  - Schedule and perform repair/ refurbish of systems
  - Perform pad washdown if required
  - Remove/ treat contaminated fluids (water/ acid, etc) and transport for disposal
  - Repair vehicle-exhaust deflectors if deteriorated

- Transport mobile launch structures/ platform to appropriate module
  - Perform systems/ structures preventive maintenance as scheduled
  - Verify facilities and systems functional for next launch
  - Service launch facility support systems
    - Replenish liquids and gasses commodities for next launch
    - Service safety, fire and emergency equipment as required
-

### 3.2 Top-Level **Horizontal** Launch Functions Sub-List

(each item expanded below):

- Verify launch facility on-line and functional
  - Position flight vehicle for/at launch site
  - Mate with facility and verify functional interfaces (if any)
  - Integrate payload and/or personnel module with vehicle and verify functional interfaces (if any)
  - Provide vehicle weather protection (if required)
    - Wind, rain, ice, lightning, etc.
  - Perform local servicing of commodities and close-out for flight if required at this module
  - Perform remote servicing of commodities and close-out for flight if required at this module
  - Ingress crew/passengers
  - Launch the vehicle
  - Recycle/ refurbish launch facility
  - Service launch facility support systems
- 

### 3.2 LAUNCH FACILITIES MODULE- **Horizontal** Launch

- Verify launch facility on-line and functional
  - Verify electrical power systems functional
  - Verify pad communications systems functional (OIS, OTV, paging/ warning, hazardous gas detection/ alarm systems)
  - Verify command and control systems functional
  - Verify propellants and gasses storage and transfer systems functional
  - Verify access and handling systems functional (elevators, cranes, safety doors, payload-unique handling equipment, weather protection, etc)
  - Verify fire-ex emergency water systems functional
- Position flight vehicle for/at launch site
  - Transport vehicle to launch site; position and secure (chock wheels) for propellant and payload servicing
  - Remove transportation hardware if required

- Mate with facility and verify functional interfaces (if any)
  - Install/ mate electrical power umbilicals to vehicle and verify all conductor continuity and free of short circuits (if required)
  - Install/ mate communications/ data umbilicals to vehicle and verify functional signal strength and noise levels if required (fiber optics, copper path, etc)
  - Verify RF/ IR communication paths functional between vehicle and facility
  - Position access systems/ equipment required (swing arms, access platforms and hardware protective kits, etc)
  - Structurally mate vehicle to facility and torque fasteners (explosive bolts) for holddown, umbilical carrier plates, and stabilizers, if required
  - Remove any temporary structural supports if required
  - Install/ mate cryogenic fluid umbilicals and leak check (if required)
  - Install/ mate toxic fluid umbilicals and leak check (NH<sub>3</sub>, MMH, N<sub>2</sub>O<sub>4</sub>, etc)
  - Install/ mate non-toxic storable liquids umbilicals and leak check (RP-1, alcohol, hydraulic fluid, coolants, H<sub>2</sub>O<sub>2</sub>, water, etc, if required)
  - Install/ mate gaseous umbilicals and leak check (GN<sub>2</sub>, GHe, GH<sub>2</sub>, GO<sub>2</sub>, air, etc)
  
- Integrate payload and/or personnel module with vehicle and verify functional interfaces (if any)
  - Perform cargo removal if desired
  - = Provide access to payload
  - = Position and connect handling equipment
  - = Demate payload from vehicle
  - = Remove payload, place on transporter and establish required services
  - = Remove payload-unique accommodations from vehicle
    - Install cargo if desired
  - = Configure vehicle and install payload-unique accommodations
  - = Clean/ verify vehicle cleanliness if required
  - = Receive, position, and install handling equipment on payload
  - = Install payload
  - = Mate payload-to-vehicle interfaces and verify functional
  
- Provide vehicle environmental protection (if required)
  - Position wind/ rain/ hail/ snow protection systems
  - Position/ check electrical continuity of lightning-sensing and protection system
  - Provide/ position vehicle thermal management and control system if used

- Perform local servicing of commodities and close-out for flight if required at this module
  - Drain and flush fluid systems as required
  - Replenish, fill or verify fluids and gasses commodities, and verify chemical purity at desired level (if appropriate at this module)
  - Recharge batteries or replace if needed
  - Lubricate and adjust subsystems as required
  - Install ordnance if desired
  - Perform flight and ground systems ordnance installation operations (if required in this module)
- = Establish RF silence (includes no-switching)
- = Remove spent ordnance and install and install new end items
- = Verify stray voltage control
- = Perform electrical mate and configure safe & arm devices
- = Perform range safety interface command checks
- = Verify functional links with space-based assets (if incorporated)
  - Perform any needed cleaning before close-out
  - Remove any access hardware or other non-flight hardware
  - Perform close-out photography if desired
  - Install close-out covers and access doors and leak check as required
- Perform remote servicing of commodities and close-out for flight if required at this module
  - Clear personnel from launch-blast danger area
  - Load main propellants for flight (cryogenic and high-pressure gasses to flight pressure)
  - Establish steady-state replenish of cryos
- Ingress crew/passengers
  - Prepare crew/ passenger module for ingress
  - Transport personnel to pad for ingress (boarding)
  - Prepare and board flight personnel (flight suits, security/ badge/ identification checks, etc)
  - Stow carry-on items
  - Seat/ secure personnel for launch/ flight environment
  - Close access hatch/ door and remove/ stow access equipment
  - Transport ground service crew to fall-back area
  - Final vehicle preparations for launch (remove wheel chocks)

- Launch the vehicle
    - Verify vehicle and environment ready for launch
  - = Ground support personnel fall-back complete
  - = Emergency fire and medical equipment and personnel on station
    - Obtain clearances to launch/ fly (if appropriate)
    - Execute auto launch sequence
    - Provide emergency abort flight personnel egress capability
  - Recycle/ refurbish launch facility
    - Secure/ safe ground systems (reactivate pre-launch-secured utilities [electrical power, lighting, fire alarms, HVAC, potable water, communications, etc], drain and purge propellant transfer systems, vent and purge high-pressure pneumatics systems, safe high-volume low-pressure facility purge systems, safe ordnance systems, replace personnel restraint systems [safety railing etc])
    - Perform facilities and systems walk-down inspections and document anomalies for repair/ refurb cycle
    - Schedule and perform repair/ refurbish of systems
    - Perform launch site washdown if required
    - Remove/ treat contaminated fluids (water/ acid, etc) and transport for disposal
    - Perform systems/ structures preventive maintenance as scheduled
    - Verify facilities and systems functional for next launch
  - Service launch facility support systems
    - Replenish liquids and gasses commodities for next launch
    - Service safety, fire and emergency equipment as required
-

### 3.3 Top-Level **Launch-Assist** (non-vertical) Functions Sub-List\_

(each item expanded below):

- Verify launch-assist facility functional and serviced
- Position flight vehicle for/at launch site
- Mate with facility and verify functional interfaces (if any)
- Integrate payload and/or personnel module with vehicle and verify functional interfaces (if any)
- Provide vehicle weather protection (if required)
  - Wind, rain, ice, lightning, etc.
- Perform local servicing of commodities and close-out for flight if required at this module
- Perform remote servicing of commodities and close-out for flight if required at this module
- Ingress crew/passengers
- Launch the vehicle
- Recycle/ refurbish launch facility
- Service launch facility support systems (including launch-assist platform systems)

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### 3.3 LAUNCH FACILITIES MODULE- **Launch-Assist** (non-vertical)

- Verify launch-assist facility functional and serviced
  - Verify electrical power systems functional
  - Verify pad communications systems functional (OIS, OTV, paging/ warning, hazardous gas detection/ alarm systems)
  - Verify command and control systems functional
  - Verify propellants and gasses storage and transfer systems functional
  - Verify access and handling systems functional (elevators, cranes, safety doors, payload-unique handling equipment, weather protection, etc)
  - Verify fire-ex emergency water systems functional
- Position flight vehicle for/at launch site
  - Transport vehicle to launch site
  - Position vehicle onto launch-assist platform and secure for propellant and payload servicing
  - Remove vehicle transportation hardware

- Mate with facility and verify functional interfaces (if any)
  - Install/ mate electrical power umbilicals from facility to launch-assist platform, and from platform to vehicle and verify all conductors continuity and free of short circuits
  - Install/ mate communications/ data umbilicals to vehicle and verify functional signal strength and noise levels if required (fiber optics, copper path, etc)
  - Verify RF/ IR communication paths functional between vehicle and facility
  - Position access systems/ equipment required (swing arms, access platforms and hardware protective kits, etc)
  - Structurally mate vehicle to launch-assist platform and torque fasteners for holddown, umbilical carrier plates, and stabilizers if required
  - Remove any temporary structural supports if required
  - Install/ mate cryogenic fluid umbilicals and leak check (if required)
  - Install/ mate toxic fluid umbilicals and leak check (NH<sub>3</sub>, MMH, N<sub>2</sub>O<sub>4</sub>, etc)
  - Install/ mate non-toxic storable liquids umbilicals and leak check (RP-1, alcohol, hydraulic fluid, coolants, H<sub>2</sub>O<sub>2</sub>, water, etc, if required)
  - Install/ mate gaseous umbilicals and leak check (GN<sub>2</sub>, GHe, GH<sub>2</sub>, GO<sub>2</sub>, air, etc)
  
- Integrate payload and/or personnel module with vehicle and verify functional interfaces (if any)
  - Perform cargo removal if desired
  - = Provide access to payload
  - = Position and connect handling equipment
  - = Demate payload from vehicle
  - = Remove payload, place on transporter and establish required services
  - = Remove payload-unique accommodations from vehicle
    - Install cargo if desired
  - = Configure vehicle and install payload-unique accommodations
  - = Clean/ verify vehicle cleanliness if required
  - = Receive, position, and install handling equipment on payload
  - = Install payload
  - = Mate payload-to-vehicle interfaces and verify functional
  
- Provide vehicle environmental protection (if required)
  - Position wind/ rain/ hail/ snow protection systems
  - Position/ check electrical continuity of lightning-sensing and protection

system

- Provide/ position vehicle thermal management and control system if used
- Perform local servicing of commodities and close-out for flight if required at this module
  - Drain and flush fluid systems as required
  - Replenish, fill or verify fluids and gasses commodities, and verify chemical purity at desired level (if appropriate at this module)
  - Recharge batteries or replace if needed
  - Lubricate and adjust subsystems as required
  - Install ordnance if desired
  - Perform flight and ground systems ordnance installation operations (if required in this module)
- = Establish RF silence (includes no-switching)
- = Remove spent ordnance and install and install new end items
- = Verify stray voltage control
- = Perform electrical mate and configure safe & arm devices
- = Perform range safety interface command checks
- = Verify functional links with space-based assets (if incorporated)
  - Perform any needed cleaning before close-out
  - Remove any access hardware or other non-flight hardware
  - Perform close-out photography if desired
  - Install close-out covers and access doors and leak check as required
- Perform remote servicing of commodities and close-out for flight if required at this module
  - Clear personnel from launch-blast danger area
  - Load main propellants for flight (cryogenic and high-pressure gasses to flight pressure)
  - Establish steady-state replenish of cryos
  - Load launch-assist platform propellants (cryos and gasses) if required
  - Power-up electrical platform power system for launch-assist function
- Ingress crew/passengers
  - Prepare crew/ passenger module for ingress
  - Transport personnel to launch area for ingress (boarding)
  - Prepare and board flight personnel (flight suits, security/ badge/ identification)

- checks, etc)
    - Stow carry-on items
    - Seat/ secure personnel for launch/ flight environment
    - Close access hatch/ door and remove/ stow access equipment
    - Transport ground service crew to fall-back area
    - Final vehicle preparations for launch (remove wheel chocks)
  - Launch the vehicle
    - Verify launch-assist system, vehicle and environment ready for launch
  - = Ground support personnel fall-back complete
  - = Emergency fire and medical equipment and personnel on station
    - Obtain clearances to launch/ fly (if appropriate)
    - Execute auto launch sequence
    - Provide emergency abort flight personnel egress capability
  - Recycle/ refurbish launch facility
    - Safe launch-assist platform if required
    - Secure/ safe ground systems (reactivate pre-launch-secured utilities [electrical power, lighting, fire alarms, HVAC, potable water, communications, etc], drain and purge propellant transfer systems, vent and purge high-pressure pneumatics systems, safe high-volume low-pressure facility purge systems, safe ordnance systems, replace personnel restraint systems [safety railing etc])
    - Retrieve/ reposition launch-assist platform to refurbish/ launch position
    - Refurbish launch-assist platform and it systems
    - Perform facilities and systems walk-down inspections and document anomalies for repair/ refurb cycle
    - Schedule and perform repair/ refurbish of systems
    - Perform launch site washdown if required
    - Remove/ treat contaminated fluids (water/ acid, etc) and transport for disposal
    - Perform systems/ structures preventive maintenance as scheduled
    - Verify facilities and systems functional for next launch
  - Service launch facility support systems (including launch-assist platform systems)
    - Replenish liquids and gasses commodities for next launch
    - Service safety, fire and emergency equipment as required
-

## 4. LANDING/RECOVERY FACILITIES MODULE

### TOP-LEVEL FUNCTIONS LIST (each item expanded below):

- Provide utilities to vehicle at motion-stop (power, cooling, purging)
  - Provide crew/passenger egress capability
  - Provide down-cargo removal capability
  - Transfer flight vehicle to next facility in flow
  - Maintain/ verify landing facility and systems functional
  - Provide support-aircraft fueling capability
- 
- Provide utilities to vehicle at motion-stop (power, cooling, purging)
    - Coordinate vehicle safeing and application of ground-supplied services as required
- = If required, check for toxic vapor leakage and take corrective action as needed: Quantity of leakage test sites on vehicle:

Sites	Quantity
Potential toxic vapor leak sites	

- = Pull samples of gas from hazardous gas detection system lines and verify no abnormal leakage and safe to start post-landing purge(s):

Interfaces	Quantity
Hazardous gas ports/sample sites	

- = Vent pressure vessels to safe post-landing level if required:

Units	Quantity
Pressure vessels	

- Position/ mate mobile ground support equipment (GSE) and verify interface
    - = Connect electrical/static ground to vehicle and verify less than one ohm
- = Chock wheels or insert landing gear pins
- = Position GSE for mate to vehicle:

Units	Quantity
Ground support equipment	

= Provide access for umbilical(s) mate: Quantity of umbilical carrier plates required for post-landing ground service:

Interfaces	Quantity
Umbilical carrier plates	

= Provide cryo vent and drain as required for vehicle safety

= Connect purge, vent, and drain ground lines to vehicle:

Interfaces	Quantity
Gaseous nitrogen	
Gaseous helium	
HVAC	
Liquids:	
- Toxic (NH <sub>3</sub> , hypergols, etc.) . . . .	_____
- Non-toxic . . . . .	_____
- Flammable (ethanol, etc.) . . . . .	_____
- Cryogenic (liquid He, etc.) . . . . .	_____
Purge, vent, and drain	
Others (specify)	

= Connect electrical ground power cables to vehicle:

Interfaces	Quantity
Alternating current	
Direct current - 28Volt	
Direct current - 270V	
Others (specify)	

= Connect cooling fluid lines to vehicle:

Interfaces	Quantity
Cooling fluid line connections	

= Connect hydraulic fluid service lines to vehicle:

Interfaces	Quantity
Hydraulic line connections	

= Connect command/control/data-link cables to vehicle:

Interfaces	Quantity
Command/ control/ data cables	

= Connect hazardous gas detection system sampling line(s) and verify:

<b>Interfaces</b>	<b>Quantity</b>
Hazardous gas detection lines	

- Provide crew/passenger egress capability
  - Verify vehicle safe
  - Position/ mate personnel access equipment
  - Open access door/ hatch and egress personnel (provide medical and/or physical assistance as required)
  - Provide crew/ passenger transport vehicle and transfer to appropriate module
- Provide down-cargo removal capability (if appropriate at landing/ recovery module)
  - Provide access to payload

= Position access equipment and platforms

= Install payload bay door GSE and open vehicle doors

- Position and connect handling equipment

= Position lifting system/ handling jacks

= Connect payload handling slings to payload and lift/ position jacks in preparation to translate payload

- Demate payload from vehicle

= Demate flight-service umbilicals from space vehicle-to-payload and stow:

<b>Interfaces</b>	<b>Quantity</b>
Power cables	
Gas lines	
Liquid lines	
Command/ control/ data lines	
Others (specify)	

= Release structural attachments and stow components:

<b>Interfaces</b>	<b>Quantity</b>
Payload structural attach locations	

- Remove payload, place on transporter and establish required services
- = Remove payload from space vehicle
- = Place payload on transporter
- = Perform structural attachment

= Mate ground service umbilicals to payload and provide services as needed

Interfaces	Quantity
Power cables	
Gas lines	
Liquid lines	
Command/ control/ data lines	
Others (specify)	

- Remove payload-unique accommodations from vehicle
- = Remove ballast required for flight vehicle CG control
- = Remove unique structural attachment fittings
- = Remove mission-unique interface fluid and power kits
- Transfer cargo module to appropriate module
- Transfer flight vehicle to next facility in flow (select one of following options):
  - **(Option 1): Taxi flight vehicle to next spaceport module**
    - = Acquire ground control clearance to taxi
    - = Taxi to designated location
  - **(Option 2): Tow flight vehicle to next facility/ spaceport module**
    - = Provide tow bar and install to tow vehicle
    - = Position tow vehicle at flight vehicle for tow
    - = Connect tow bar to flight vehicle
    - = Release or verify flight vehicle nose wheel steering unlocked and release brakes
    - = Remove crew access equipment/platforms and return to park site
      - = Remove wheel chocks or gear locking pins and stow
      - = Disconnect ground cable from flight vehicle
      - = Verify tow route clear and safety/security supporting
      - = Tow flight vehicle to next facility
  - **(Option 3): Self-ferry flight vehicle to next facility**
    - = Freeze-proof appropriate critical systems for high-altitude flight:

Systems	Quantity
Freeze Prevention Required	
GSE Units Required	

= Replenish commodities required for self-ferry flight:

<b>Commodities</b>	<b>Pounds</b>
Fuels (specify)	
Propellants - Oxidizer	
Propellants - Fuel	
Gases (specify)	
Reactants (specify)	
Others (specify)	

= Load ferry-unique software if required

<b>Software</b>	<b>Lines</b>
Ferry-unique	

= Configure flight vehicle systems (special heaters, etc.)

= Recharge or replace batteries

<b>Batteries</b>	<b>Quantity</b>	<b>Amp Hrs.</b>
Replace		
Recharge		

= Provide/position heavy equipment support (jacks, cranes, lifting harnesses, personnel access equipment, etc.)

= Install ferry-unique propulsion systems, verify functional and leak check

<b>Systems</b>	<b>Quantity</b>	<b>Tot. Wt., lb.</b>	<b>Qty. Veh. I/Fs</b>
Air-breathing engines			
Rocket engines			
Fuel/ propellant tankage			

= Install special covers/ fairings, etc.

<b>Units</b>	<b>Quantity</b>	<b>Weight</b>
Ferry-unique vehicle fairings		

= Verify all ferry-critical systems functional

= Taxi for takeoff, perform pre-flight checklist, obtain flight clearance

= Fly to next facility site

- (**Option 4**): **Ferry flight vehicle to next module** (airborne configuration)

Verify cranes/ lifting devices configured and ready to support space vehicle lift-to-mate activity

- = Space vehicle lifting harness attached to crane(s) hooks
- = Lighting and support GSE (personnel lifts, generators, etc.) ready
- = Weather prediction meets requirements for space vehicle on-the-hook activity

Tow flight vehicle to ferry-aircraft mate site

- = Provide tow bar and install to tow vehicle
- = Position tow vehicle at flight vehicle and connect tow bar to space vehicle
- = Release or verify space vehicle nose wheel steering unlocked and release brakes
- = Remove crew access equipment/platforms and return to park site
  - = Remove wheel chocks or gear locking pins and stow
  - = Verify tow route clear and safety/security supporting
  - = Tow space vehicle to ferry-aircraft mate site
  - = Position vehicle in mate/ demate device/ area
  - = Install static ground cable to space vehicle

Space vehicle ferry preparations

- = Freeze-proof appropriate critical systems for high-altitude flight:

<b>Systems</b>	<b>Quantity</b>
Freeze prevention required	
GSE units required	

- = Configure flight vehicle systems (special heaters, etc.)
- = Provide/position heavy equipment support (jacks, cranes, lifting harnesses, personnel access equipment, etc.)
  - = Install special covers/fairings, and ferry-unique hardware (e.g., engine and aero-surface structural supports, etc.)

<b>Units</b>	<b>Quantity</b>	<b>Weight</b>
Ferry-unique vehicle fairings		

- = Verify all ferry-critical systems functional

Option for under-wing/ belly-ferry configuration:

- = Move ferry aircraft to into mate position
- = Attach aircraft-provided lifting harness; or position jacks at space vehicle
- = Position/ lift vehicle to aircraft-mate position

- = Perform structural attachment to aircraft
- = Remove and stow jacks as appropriate

Option for above-wing/ back-ferry configuration:

- = Position personnel access equipment (platforms, high-rangers, etc.)
- = Lower lifting harness and attach to space craft
- = Position/lift flight vehicle clear of surface:

<b>Systems</b>	<b>Quantity</b>	<b>Rated Load, lb.</b>
Jacks		
Cranes		
Hoists		
Hydrasets		
Structural Facility		

- = Retract and stow landing gear
- = Continue vehicle lift to mate elevation
- = Move ferry aircraft into mate position
- = Perform structural mate to ferry vehicle

Ferry flight

- = Taxi for takeoff, perform pre-flight checklist, obtain flight clearance
- = Fly to next facility/ module site
- = Land ferry aircraft and taxi to mate/ demate area/ device
  - o Tow ferry aircraft and vehicle into demate position
  - o Connect static ground to aircraft/ space vehicle

Under-wing/ belly-ferry option

- = Perform structural disconnect from aircraft and lower to near-surface
- = Lower vehicle landing gear and continue lowering vehicle to surface
- = Tow ferry aircraft to park site

Above-wing/ back-ferry option

- = Position personnel access equipment (platforms, high rangers, etc.)
- = Lower space craft lifting harness to mate position
- = Attach lifting device/ harness to space vehicle
- = Perform structural disconnect from aircraft
- = Lift space vehicle; disconnect aircraft ground cable; and tow ferry aircraft to park site

- = Lower space vehicle to near-surface
- = Lower vehicle landing gear and continue lowering vehicle to surface
- = Disconnect lifting harness, remove from crane and stow

Tow flight vehicle to next facility/ spaceport module

- = Provide tow bar and install to tow vehicle
- = Position tow vehicle at flight vehicle for tow
- = Connect tow bar to flight vehicle
  - = Release or verify flight vehicle nose wheel steering unlocked and release brakes
  - = Remove wheel chocks or gear locking pins and stow
  - = Verify tow route clear and safety/security supporting
  - = Tow flight vehicle to next facility/ module

- Maintain/ verify landing facility and systems functional
  - Verify landing aides functional (e.g., lights, RF beacons, MSBLS, differential GPS, over-run barriers, etc)

<b>Systems</b>	<b>Quantity</b>
Landing aides	

- Verify static ground poise 1 ohm or less
- Verify wildlife/ bird abatement equipment functional
- Verify security fencing and gates intact and functional

- Verify ground support systems functional:

<b>Systems</b>	<b>Quantity</b>
Power (fixed and mobile)	
Cooling (ditto)	
Lighting (ditto)	
Communications (ditto)	
Cargo access and handling	
Emergency fire/ medical	
Others (specify)	

- Verify vehicle-transport unique support systems on-line (towing/ ferry

aircraft mate-demate, lifting harness and cranes in proof-load, personnel elevated access equipment, etc)

- Maintain/ refurbish landing facility and surfaces as required
  - Provide support-aircraft fueling capability
    - Verify storage and transfer systems functional (replenish fuel as needed)
    - Verify portable fuel vehicles available and functional as required
    - Perform aircraft refueling as required
-

## 5. VEHICLE TURNAROUND FACILITIES MODULE

### TOP-LEVEL FUNCTIONS LIST (each item expanded below):

- Prepare facility for space vehicle arrival
  - Receive vehicle at this facility
  - Perform safeing if required (ordnance, cryos, etc.)
  - Perform inspection and checkout to verify health of system
  - Perform cargo removal if desired
  - Install cargo if desired
  - Perform LRU remove-and-replace; repair as needed
  - Service commodities and perform close-out if desired
- 

- Prepare facility for space vehicle arrival
  - Work control system on-line and functional
  - Information and management systems functional

<b>Systems</b>	<b>Quantity</b>
Command/ control terminals	
LAN (personal computers)	
Printers	
Readers	

- Logistics staging area/ tool crib(s) sited and operational

- Verify hazardous warning systems functional:

<b>Systems</b>	<b>Quantity</b>
Paging system	
Toxic vapor detectors	
Smoke/ fire detectors	
Oxygen depletion detectors	
Hydrogen vapor/ fire detectors	

- Verify firex system functional

<b>Systems</b>	<b>Quantity</b>
Pumps, tanks, and controls	
Hose Reels	
Sprinklers	
Fire extinguishers	

- Environmental contamination control

<b>Systems</b>	<b>Quantity</b>
Toxic liquid spill handling/ control	
- Water flush and drain . . . . .	
- Catch basin(s) . . . . .	
- Ventilation and air scrubber(s)	

- Verify lifting devices/ cranes functional

<b>Systems</b>	<b>Quantity</b>
Bridge cranes	
Derricks/ hoists	
Mobile cranes	
Jacks (facility/portable hydrasets etc.)	
Manlifts	

- Clean/ verify facility cleanroom

= Filters serviced, sampling systems and HVAC functional

<b>Clean Rooms</b>	<b>Quantity</b>	<b>Class</b>
Total flight vehicle area		
Payload-specific area		
Sampling system(s)		
Filter system(s)		
Air handlers		
Major doors and seals		
Shoe cleaners		
Personnel attire (bunny suits)		

- Verify vehicle, facility, and GSE power support systems functional:

<b>Interfaces</b>	<b>Quantity</b>
Alternating current	
Direct current - 28Volt	
Direct current - 270V	

Power conditioning/ filtering (Spike/ surge protection)	
Uninterruptible supplies (UPS)	
Back-up generators	
Grounding systems	
High voltage GSE (13KVA, etc)	
Lightning protection	
Others (specify)	

- Verify command and control systems functional and software ready and verified:

<b>Systems</b>	<b>Quantity</b>
Main propulsion functions	
Auxiliary propulsion functions	
Fuel-cell power functions	
Guidance-nav-control functions	
Purge, vent, drain functions	
Hydraulic power functions	
Electrical power functions	
Cooling systems (thermal mgmt.)	
Communication & tracking systems	
Life support system functions	
Utilities feed systems for module;	
- Power . . . . .	_____
- Water . . . . .	_____
- High pressure gases . . . . .	_____
- Firex (Halon, etc.) . . . . .	_____
- HVAC . . . . .	_____
- OTV . . . . .	_____
- OIS . . . . .	_____
- Mechanical subsystems . . . . .	_____
- Data processing subsystems . . . . .	_____
- Others (specify) . . . . .	_____

- Lighting/ illumination functional and ready

<b>Systems</b>	<b>Quantity</b>
General area lighting	
Special lighting/ cleanroom functions	
Portable lights	

Emergency lighting	
--------------------	--

- Verify GSE and facility systems functional and ready to support:

<b>Systems (mechanical hardware; hoses, control panels, etc.)</b>	<b>Quantity</b>
Main propulsion	
Auxiliary propulsion	
Fuel-cell power	
Guidance-nav-control	
Purge, vent, drain	
Hydraulic power	
Electrical power	
Cooling systems (thermal mgmt.)	
Communication & tracking systems	
Life support system	
Utilities feed systems for module;	
- Power . . . . .	_____
- Water . . . . .	_____
- High pressure gases . . . . .	_____
- Firex (Halon, etc) . . . . .	_____
- HVAC . . . . .	_____
- OTV . . . . .	_____
- OIS . . . . .	_____
- Mechanical subsystems . . . . .	_____
- Data processing subsystems . . . . .	_____
- Others (specify) . . . . .	_____

- Roll-up style vehicle shelter/ mobile ground processing structure positioned for flight vehicle arrival
- Open vehicle access doors, verify transfer path clear

- Receive vehicle at this facility
- Vehicle roll-in, spot, and secure

**(Option 1): Vehicle taxis to predetermined spot**

**(Option 2): Vehicle is towed to predetermined spot**

- = Detach tow vehicle and return to park site
- = Remove tow bar and stow

**(Option 3): Tow or drive transporter with vehicle to predetermined spot**

**Verify cranes/ lifting devices configured and ready to support space vehicle lifting activity**

- = Space vehicle lifting harness attached to crane(s) hooks
- = Lighting and support GSE (personnel lifts, generators, etc.) ready
- = Weather prediction meets requirements for space vehicle on-the-hook activity

**Tow/ transport flight vehicle to lift site**

- = Provide tow bar and install to tow vehicle
- = Position tow vehicle at flight vehicle and connect tow bar to space vehicle
- = Release or verify space vehicle nose wheel steering unlocked and release brakes
- = Remove crew access equipment/platforms and return to park site
  - = Remove wheel chocks or gear locking pins and stow
  - = Verify tow route clear and safety/security supporting
  - = Tow/ transfer space vehicle to predetermined site
  - = Position vehicle in mate/ demate device/ lifting area
  - = Install static ground cable to space vehicle

**Lift vehicle from ground-level or transporter**

- = Position access to attach lifting hardware
- = Translate crane hook(s) and lifting fixtures to lift site over vehicle
- = Attach lifting fixtures to vehicle
- = Release vehicle-to-transporter attachments
- = Remove access stands/ platforms
- = Lift vehicle clear of ground or transporter as appropriate
- = Remove transporter and return to parksite
  - = Lower vehicle onto supports at predetermined site
- = Reposition access to remove lifting fixture
- = Detach lifting hardware, secure crane and stow fixtures
- = Remove access and return to parksite/ stow

**Environmental protection**

**(Option 1): Close major facility vehicle-entry doors**

**(Option 2): Move vehicle shelter into position and secure**

- Jack and level vehicle and secure vehicle for processing

- Bring-up and position vehicle access platforms
- Perform safeing if required (ordnance, cryos, etc.)
  - Connect ground umbilicals and vehicle electrical ground
  - Depressurize high pressure bottles to safe level
  - Drain cryo residuals
  - Drain and purge toxics if system entry required
  - Safe all ordnance
  - Purge compartments and verify safe for personnel entry
- Perform inspection and checkout to verify health of system
  - Inspect external and internal systems  
for out-of-spec conditions (contamination, damage and critical wear)
  - Verify minimum critical component/ subsystems functional (primary and redundant)
- Perform cargo removal if desired
  - Provide access to payload
  - Position and connect handling equipment
  - Demate payload from vehicle
  - Remove payload, place on transporter and establish required services
  - Remove payload-unique accommodations from vehicle
- Install cargo if desired
  - Configure vehicle and install payload-unique accommodations
  - Clean/ verify vehicle cleanliness if required
  - Receive, position, and install handling equipment on payload
  - Install payload
  - Mate payload-to-vehicle interfaces and verify functional
- Perform LRU remove-and-replace; repair as needed
  - Assemble tools, materials or shop support items
  - Provide access as required
  - Position special handling equipment
  - Prepare subsystem for LRU removal/ repairs (depressurize/ remove power)
  - Demate LRU from vehicle
  - Remove from vehicle and place on transporter/ move to logistics for disposition
  - Receive replacement LRU from logistics and prepare for installation

- Prepare subsystem for LRU installation (inspection, cleaning, alignment and other subsystem support as needed)
  - Install replacement LRU and remove special handling/ access equipment
  - Perform retest to verify functional (power-up, leak check, test function)
  - Repair damaged item in-place (restore-to-spec) when needed
- Service commodities and perform close-out if required at this module
    - Drain and flush fluid systems as required
    - Replenish, fill or verify fluids and gasses commodities, and verify chemical purity at desired level (if appropriate at this module)
    - Recharge batteries or replace if needed
    - Lubricate and adjust subsystems as required
    - Install ordnance if desired
    - Perform flight and ground systems ordnance installation operations (if required in this module)
  - = Establish RF silence (includes no-switching)
  - = Remove spent ordnance and install and install new end items
  - = Verify stray voltage control
  - = Perform electrical mate and configure safe & arm devices
  - = Perform range safety interface command checks
  - = Verify functional links with space-based assets  
(if incorporated)
    - Perform any needed cleaning before close-out
    - Remove any access hardware or other non-flight hardware
    - Perform close-out photography if desires
    - Install close-out covers and access doors and leak check as required
    - Remove flight vehicle ground umbilicals
    - Perform weight and CG measurement if required
    - Move to next module
-

## 6. VEHICLE ASSEMBLY/INTEGRATION FACILITIES MODULE

### TOP-LEVEL FUNCTIONS LIST: (each item expanded below):

- Mate flight element to ground element
  - Assemble/mate flight elements if required (stages, ordnance, cargo, etc.)
  - Perform interface verification
  - Perform servicing/close-out if required
  - Transfer elements and interface hardware
  - Transfer flight vehicle to next module
- 
- Mate flight element to ground element
    - Verify facility configured for operation
    - Verify unique GSE functional and staged for operation
    - Provide personnel-access equipment for operation (platforms, stands, manlifts, etc.)
    - Station technical/fire/medical support personnel and verify communications operational
  - **(Option 1): Mate vehicle to transporter/ erector**
    - = Position vehicle for lifting
    - = Attach lifting device(s) and demate structural attachments
    - = Lift vehicle, transfer and mate to ground transporter/ erector
  - **(Option 2): Mate flight vehicle to launcher**
    - = Position vehicle for lifting
    - = Attach lifting device(s) and demate structural attachments
    - = Lift vehicle, transfer and mate to launcher
  - **(Option 3): Mate vehicle to launch assist system (mag-lev, sled, etc.)**
    - = Position vehicle for lifting
    - = Attach lifting device(s) and demate structural attachments
    - = Lift vehicle, transfer and mate to launch assist system
  - Verify structural attachment of above option, remove unique GSE and stow

- Mate flight vehicle to ground servicing system

<b>Systems</b>	<b>Quantity</b>
Power cables	
Gas lines	
Liquid lines	
Command/ control/ data lines	
Others (specify)	

- Assemble/mate flight elements if required (stages, ordnance, cargo, etc.)

<b>Flight Elements</b>	<b>Quantity</b>
Stages	
Drop tanks	
Propulsion units (OMS, RCS. etc.)	
Payload(s) modules	
Ordnance packages	

- Verify unique GSE functional and staged for operation
- Provide personnel-access equipment for operation (platforms, stands, manlifts, etc.)
- Mate stage-to-stage/ major elements (e.g., drop tank)
- = Position flight element for lift and mating
- = Attach lifting device(s) and demate structural attachments
- = Lift element, transfer and mate to vehicle
- Verify structural attachment, remove unique GSE and stow
- Mate interstage services (umbilicals/ electrical/ propellants, etc.)

- Mate element to ground servicing system

<b>Systems</b>	<b>Quantity</b>
Power cables	
Gas lines	
Liquid lines	
Command/ control/ data lines	
Others (specify)	

- Mate payload to launch vehicle

**(Option 1): Containerized payload**

- = Verify facility cleanliness and environmental controls in place
- = Verify vehicle payload bay cleanliness adequate for operation
- = Position payload for lift and mating
- = Provide access to payload (platforms, open doors, remove environmental covers, etc.)
- = Attach lifting device(s) and demate structural attachments
- = Lift payload, transfer and mate to flight vehicle

**(Option 2): Payload built-into vehicle** (e.g., Atlas, Delta, Shuttle, Titan)

- = Verify facility cleanliness and environmental controls in place
- = Verify vehicle payload bay cleanliness adequate for operation
- = Provide engineering design for unique payload-to-vehicle cargo bay adapter system(s)
  - = Provide manufacture of above unique adapter hardware
  - = Schedule and perform unique adapter installation in vehicle payload bay
- = Position payload for lift and mating
- = Provide access to payload (platforms, open doors, remove environmental covers, etc.)
- = Attach lifting device(s) and demate structural attachments
- = Lift payload, transfer and mate to flight vehicle

- Verify structural payload attachment, remove unique GSE and stow
- Mate payload to vehicle support servicing systems

Systems	Quantity
Power cables	
Gas lines	
Liquid lines	
Command/ control/ data lines	
Others (specify)	

- Stage and install ordnance and mate electrically
- = Stage ordnance from ground storage
- = Mechanically install ordnance hardware
  - o Ground-to-flight system
  - o Flight element-to-flight element
  - o Flight element-to-payload

- o Intra-payload unique
- = Verify circuits safe (resistance and voltage) and connect all items

- Verify structural integrity, alignment, torque, etc.
- = Flight element-to-ground systems
- = Flight element-to-flight element
- = Payload-to-flight element

- Perform interface verification

- Fluid system leak checks

Interfaces	Quantity
Gaseous nitrogen	
Gaseous helium	
HVAC	
Liquids:	
- Toxic (NH3, hypergols, etc.) . . .	_____
- Non-toxic . . . . .	_____
- Flammable (ethanol, etc.) . . . . .	_____
- Cryogenic (liquid He, etc.) . . . . .	_____
Purge, vent, and drain	
Others (specify)	

- Electrical systems continuity/ integrity/ RF

Interfaces	Quantity
Alternating current	
Direct current - 28Volt	
Direct current - 270V	
Command/ control/ data lines	
Others (specify)	

- Perform servicing/close-out if desired

- Close-out interfaces/ protective covers/ fairings
- = Stage protective covers/ fairings (e.g., thermal; aerodynamic; electrical connector, etc.)
- = Install protective covers/ fairings
- = Apply TPS where required (blankets, foam, tile, etc.)
- Take inspection and close-out photos

- Service fluids (initiate purges, fill storables)

<b>Interfaces</b>	<b>Quantity</b>
Gaseous nitrogen	
Gaseous helium	
HVAC	
Liquids:	
- Toxic (NH <sub>3</sub> , hypergols, etc.) . . .	_____
- Non-toxic . . . . .	_____
- Flammable (ethanol, etc.) . . . . .	_____
- Cryogenic (liquid He, etc.) . . . . .	_____
Purge, vent, and drain	
Others (specify)	

- Verify batteries functional
- Verify all non-flight hardware and tools removed and stowed
- Close and secure vehicle access doors (equipment and personnel)
- Remove personnel access systems (platforms, stands, protective devices and covers)

- Transfer elements and interface hardware non-flight items (caps, plugs, tags, etc.) and ground transporters to storage locations

- Ordnance containers
- flight element handling hardware (slings, shackles, strong backs, etc.)
- Ground support systems (servicing hoses, portable test equipment, etc.)

<b>Interfaces</b>	<b>Quantity</b>
Gaseous nitrogen	
Gaseous helium	
HVAC	
Liquids:	
- Toxic (NH <sub>3</sub> , hypergols, etc.) . . .	_____
- Non-toxic . . . . .	_____
- Flammable (ethanol, etc.) . . . . .	_____
- Cryogenic (liquid He, etc.) . . . . .	_____
Purge, vent, and drain	
Others (specify)	

- Element transporters (payload and flight)

<b>Flight Elements</b>	<b>Quantity</b>
------------------------	-----------------

Stages	
Drop tanks	
Propulsion units (OMS, RCS. etc.)	
Payload(s) modules	
Ordnance packages	

- Transfer flight vehicle to next module

---

## 7. VEHICLE DEPOT MAINTENANCE FACILITIES MODULE

### TOP-LEVEL FUNCTIONS LIST: (each item expanded below):

- Vehicle overhaul, inspection/verification, and modifications (structural, flight controls, etc.)
  - Modular element overhaul and inspection/verification (OMS-RCS pods, SSME, wheels/tires, TPS, etc.)
  - Hot test propulsion hardware
  - Spaceport software upgrades (non-flight)
- 

- Vehicle overhaul, inspection/verification, and modifications (structural, flight controls, etc.)
    - Transport to module and offload if appropriate
    - Place in work stand; jack and level
    - Disassemble/ gain access to perform major structural inspections/ assessment and repair/ replacement (major NDE effort)
    - Perform internal inspection of vehicle tanks and pressure vessels (major NDE effort) for structural assessment including bonding and delamination and cleanliness verification
    - Perform desired modifications
    - Replace subsystem components for modified elements or those that are “limited-life-expired”
    - Perform LRU remove-and-replace; repair as needed
- = Assemble tools, materials or shop support items
- = Provide access as required
- = Position special handling equipment
- = Prepare subsystem for LRU removal/ repairs (depressurize/ remove power)
- = Demate LRU from vehicle
- = Remove from vehicle and place on transporter/ move to logistics for disposition
- = Receive replacement LRU from logistics and prepare for installation

- = Prepare subsystem for LRU installation (inspection, cleaning, alignment and other subsystem support as needed)
- = Install replacement LRU and remove special handling/ access equipment
- = Perform retest to verify functional (power-up, leak check, test function)
  - = Repair damaged item in-place (restore-to-spec) when needed
- Inspect/ test cable harness, tubing, plumbing for verification to design specification; replace as necessary
- Reassemble all vehicle systems to design specification
- Perform controls dynamic response test and verify to design specification
- Perform system and subsystem retest to verify all systems (including all levels of redundancy) are functional to design requirements; and vehicle certified for flight operations (multiple flight certification)
- Remove non-flight items as required and return to next module
- Modular element overhaul and inspection/verification (OMS-RCS pods, SSME, wheels/tires, TPS, etc.)
  - Remove/ replace modular element from vehicle and move to overhaul module
  - Repeat all above functions
  - Perform LRU remove-and-replace; repair as needed
- = Assemble tools, materials or shop support items
- = Provide access as required
- = Position special handling equipment
- = Prepare subsystem for LRU removal/ repairs (depressurize/ remove power)
- = Demate LRU from vehicle
- = Remove from vehicle and place on transporter/ move to logistics for disposition
- = Receive replacement LRU from logistics and prepare for installation
- = Prepare subsystem for LRU installation (inspection, cleaning, alignment and other subsystem support as needed)
- = Install replacement LRU and remove special handling/ access equipment
- = Perform retest to verify functional (power-up, leak check, test function)
- = Repair damaged item in-place (restore-to-spec) when needed
  - Install protective covers for interfaces
  - Prepare overhauled element and transport back to vehicle
- Hot-test propulsion hardware
  - Transport and install element in test stand

- Mate element and test stand and verify leak-free and electrically functional
  - Install all unique instrumentation and verify function
  - Prepare test stand for support of hot-test
  - Perform functional tests of all element systems (vehicle and ground)
  - Service all commodities (consumables)
  - Clear controlled area for test
  - Perform hot-fire test
  - Safe and secure systems
  - Analyze data and verify performance (certify for flight use
  - Demate umbilical and remove element from test stand
  - Prepare element for shipping/ transport
  - Move to vehicle for re-installation
-

## **8. SPACEPORT SUPPORT INFRASTRUCTURE FACILITIES MODULE**

### TOP-LEVEL FUNCTIONS LIST:

- Shops and labs (machine, precision cleaning, NDE, chemical, sampling, failure analysis, battery, avionics, tubing fab, etc.)
  - Photography
  - Fire protection
  - Medical
  - Security
  - Library (technical documents)
  - Utilities (waste, water, electrical, etc.)
  - Roads and grounds
  - Food
  - Heavy equipment (mobile cranes, generators, lights, proof-load, etc.)
  - Communication/ information services
  - Ground transportation services
  - Environmental compatibility management
  - Pyrotechnic storage and handling
  - Personal environmental protection equipment
  - Facility maintenance services and shops (plumbing, welding, sand blast and paint, electrical, HVAC, water, mechanical, roofing, etc.)
-

## 9. CONCEPT-UNIQUE LOGISTICS FACILITIES MODULE

### TOP-LEVEL FUNCTIONS LIST: (each item expanded below):

- Propellants (acquisition, storage, distribution, conditioning/verification)
  - Other fluids and gasses and unique consumables
  - LRU replacement hardware (flight and ground systems)
- 
- Propellants (acquisition, storage, distribution, conditioning/verification)
    - Acquisition
    - Storage
    - Distribution
    - Conditioning
    - Sampling/ verification
    - Waste disposal management
  - Other fluids and gasses and unique consumables
    - Acquisition, preparation and fabrication
    - Storage
    - Distribution
    - Sampling/ verification
    - Waste disposal management
  - LRU replacement hardware (flight and ground systems)
    - Acquisition (LRUs, repair kits, determine quantities)  
preservation requirements
    - Storage and preservation including shelf-life control
    - Component failure assessment/ analysis, and disposition
    - Component repair (cleaning, softgoods, replacement, assembly, adjustment,  
and functional verification testing)
    - Fabrication of tubing and cabling assemblies and TPS
    - User-support kitting and distribution
-

## **10. TRANSPORTATION SYSTEM OPERATIONS PLANNING AND MANAGEMENT OFFICE MODULE**

### TOP-LEVEL FUNCTIONS LIST:

- Customer relations (sales, requirements)
  - Vehicle manifesting and scheduling
  - Ground systems scheduling and management
  - Software production (upgrades and mission unique)
  - Personnel management
  - Sustaining operations engineering (vehicle and facilities)
  - Work control
  - Public affairs
  - Economic development
  - Business management (contracts, procurement, legal, financial)
  - Advanced planning
  - SR&QA
-

## 11. EXPENDABLE ELEMENT FACILITIES MODULE

### TOP-LEVEL FUNCTIONS LIST: (each item expanded below):

- Receiving and inspection
  - Storage
  - Assembly/ close-out
  - Checkout to verify functions
  - Conditioning if required (purging, temperature and humidity control)
  - Perform design modifications (deferred work)
- 

- Receiving and inspection
  - Transport/ offload
  - Verify free of shipping/ handling damage
  - Data-pack receiving for hardware accountability
- Storage
  - Handling for receiving and departure
  - Active preservation
  - Security control
- Assembly/ close-out
  - Close-out structural attachments if needed
  - Attach any ordnance hardware and cabling if required
- Checkout to verify functions
  - Valve-timing checks
  - Fluid leak checks
  - Electrical component functionals
  - Electrical network/ connector verifications
  - Mechanical mechanisms functionals (disconnects, etc.)
  - Flight sequence verification checks
- Conditioning if required (purging, temperature and humidity control)
  - Purging tanks and lines sampling verification

- Cleanliness verification
  - Temperature and humidity monitoring/ control
  
  - Perform design modifications (deferred work)
    - Vehicle/ element access accommodations
    - Environmental control for personnel safety
    - Configuration and process control systems
    - Materials management
    - Engineering/ safety special requirements
-

## 12. COMMUNITY INFRASTRUCTURE MODULE

### TOP-LEVEL FUNCTIONS LIST:

- Shelter (housing)
  - Utilities (water, power, communications, sewage, etc.)
  - Transportation support (roads, rail, etc.)
  - Educational support
  - Police/fire protection
  - Religious support
  - Consumer retail support
  - Medical support/ hospitals, etc.
  - Financial institutions
-